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Public Priorities for the Post-War Reconstruction of Ukraine's Energy Sector

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Abstract

The Russian invasion of Ukraine has resulted in the large-scale destruction of many cities across the country. Although the war has not yet ended, there will come a time when the conflict concludes, and reconstruction efforts will begin. Global experiences show that the first step in preparing for post-war reconstruction is to assess the level of destruction. Additionally, it is essential to understand people's needs and priorities. Otherwise, reconstruction activities may fail to address the existing challenges and actual needs of local communities. This study aims to explore post-war reconstruction priorities of Ukrainians, with special focus on the energy sector and particularly the district heating facilities. During hostilities, a significant part of Ukraine's energy infrastructure was damaged or destroyed, which will be an essential sector in the recovery of other sectors. Research work involved undertaking an online survey with questions focusing on Ukrainians' assessment of the importance of the reconstruction of the energy sector. A total of 420 people from different regions of Ukraine, different age groups and professional backgrounds participated in the survey. Results show that a significant number of Ukrainian citizens have a high level of energy awareness. Thus, when asked what measure of post-war reconstruction of the energy sector they consider of high importance, 64% of respondents chose the answer "Reconstruction using energy-saving construction technologies and energy-efficient engineering systems, even if it takes more time". Furthermore, 32% of respondents are ready to pay more for district heating services if alternative energy sources are used to generate heat.

Keywords: online survey; energy infrastructure; district heating systems; post-war reconstruction; priorities; alternative energy sources.

1. Introduction

Ukraine's energy system has been under a constant wave of targeted Russian attacks since February 2022. The Russian Federation has occupied more than 18 GW of electricity-generating capacity, including Europe's largest facility, the Zaporizhzhia nuclear power plant (NPP). The Kakhovka and Dniprovska hydropower plants (HPPs), as well as the Zmiivska and Trypilska thermal power plants (TPPs), were completely destroyed. Private thermal power plants suffered critical damage (over 80%), including Ladyzhynska, Burshtynska, Dobrotvirska, Kurakhivska, Kryvyi Rih and Prydniprovska TPPs. In addition, all oil refineries on the territory of Ukraine were destroyed [1]. Nevertheless, with international support, the Ukrainian government managed to restore 3 GW by installing more power generating equipment and making repairs to damaged energy infrastructure. Consumers, mainly businesses, installed distributed generation facilities throughout the country, mainly gas engines, gas turbines and cogeneration

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units. Thus, by the end of 2024, almost 1 GW of additional power was generated for domestic needs, which allowed reducing the load on the power system. In addition, measures are in place in Ukraine to limit energy consumption for industry, business and ordinary consumers, and calls for energy conservation do not cease even on days with stable power supply. To provide additional electricity, the capacity of electricity imports from the EU increased from 1.7 GW to 2.1 GW by December 1, 2024 [2].

District heating systems are an integral part of the country's energy infrastructure. And ensuring energy security in the field of district heating is an important step towards sustainable development and prosperity of the country. However, district heating systems have also suffered significant damage from shelling. Thus, as of April 2024, 10 thermal power plants were completely destroyed and another 15 were damaged in the territories where hostilities are underway. For example, the destroyed Kremenchuk Combined Heat and Power plant (CHP) (Poltava region) covered about 70% of the city's needs, that is, about 180 thousand residents, who could have been left without heat and hot water for the entire heating season if not for timely repair work. In addition, according to preliminary data, 863 boiler houses were partially damaged or completely destroyed as a result of the fighting, most of them in Kharkiv, Kyiv, Chernihiv, Donetsk and Mykolaiv regions. Also, 183 central substations were partially damaged or completely destroyed, and over 355 kilometres of heating networks were beyond repair [3]. A final assessment of the total damage will only be possible after the end of hostilities, but it is already necessary to consider strategies for rebuilding energy infrastructure, particularly district heating systems.

2. Analysis of recent research

The ways of restoration of Ukraine in the post-war period are a relevant object of research by both Ukrainian and foreign scientists. According to Farenyuk et al. [4], the national priority is to provide housing for people of Ukraine who have lost their homes or have been forced to leave them. This is due to the fact that the largest share in the total loss caused by the Russian military invasion of Ukraine is damage and destruction of residential buildings. As of the end of 2024, these losses amounted to 35.3% of the total, and the total area of damaged and destroyed buildings is 9% of the total area of the housing stock of Ukraine [4]. For the rapid restoration of housing stock, they propose to use the method of large-panel construction, which allows reducing the time of construction, reduce the amount of construction waste, improving the quality of structures through the production of elements in factory conditions. Nazarenko O. at al. [5] suggest that the reconstruction of housing in the post-war years should be carried out on the principles of biosphere compatibility, namely using building materials, which in their composition and characteristics contribute to the minimization of the use of natural resources, do not harm the environment.

In the reconstruction of the industrial sector Deineka et al. [6] see the priorities of the restoration of mechanical engineering and the defense-industrial complex, as well as enterprises of metallurgical, food, chemical, pharmaceutical and woodworking industries, as well as the development of new fields of activity, such as bio- and nanotechnology. The authors [7] consider the transport sector of Ukraine to be one of the most vulnerable sectors of the economy, since its enterprises are in many cases goals for attacks. The authors emphasize the unconditional priority of the post-war reconstruction of the transport sector and offer a comprehensive approach to financing, investing and restoring the transport sector of Ukraine. Simakhova considers the main aspects of the post-war socialization of the Ukrainian economy. She identifies eight aspects: rehabilitation and social support for victims and veterans, employment of the unemployed population, migration processes and return of citizens, education and professional training, social justice and reduction of inequality, health care reform, environmental transformation [8].

The energy sector of Ukraine also suffered significant damage, as mentioned above. Therefore, many studies are devoted to determining the steps and priorities of its post-war reconstruction. So Grand and Svionik [9] have identified eight priority tasks to strengthen the country's energy security: increase in energy production for import substitution; creation of strategic reserves of coal, nuclear fuel, oil and gas; diversification of sources of supply of energy resources; development of alternative energy; ensuring the autonomous operation of the united power system of Ukraine on the basis of the development of energy infrastructure; deepening of Ukraine's international cooperation with partner countries in the field of energy security; providing cybersecurity of energy infrastructure; improvement of the system of state regulation and management of the energy sphere of the state. Sirenko et al. [10], to improve the situation in the energy sector of Ukraine, distinguish the following directions: development of renewable energy, improvement of energy efficiency of components of the power system, modernization of energy infrastructure, promotion of distributed generation, reforming the energy sector. Savchenko proposes the stages of achieving the

energy efficiency of centralized heat supply systems both during modernization and in the construction of new centralized heat supply systems, in particular in the post-war reconstruction of Ukraine [11].

The complexity of modernization and restoration of the district heating system of Ukraine is related to the existing condition of facilities of thermal power sector. Thus, most thermal networks and heat generating installations were built in the 1970s and 1980s. Therefore, the main problem of existing district heating systems is the long service life of its equipment, from which the inefficient use of energy resources and significant heat losses from the pipelines of thermal networks.

Since the 2000s, heat-generating enterprises have been implementing measures to modernize district heating systems. The first step in energy savings was the use of pre-isolated polyurethane pipelines during repairs of the existing thermal network. Further steps in the modernization of heating systems included mandatory metering of heat energy and the installation of individual heat points at heat energy consumers. According to the requirements of the Law of Ukraine "On Commercial Accounting of Heat Energy and Water Supply", it is prohibited to connect residential and non-residential buildings to external engineering networks without installing commercial accounting units in them, in particular heat and hot water meters. In Lviv, as of 2021, 98% of houses have house heat meters [12]. Installing individual substations at consumers requires significant capital costs, but to be able to regulate heat supply and save on heat energy bills, consumers can independently look for investors or attract credit funds. For example, in Lviv, 409 individual heat points were installed with funds from the European Bank for Reconstruction and Development from 2019 to 2022. The project covered the entire Sykhiv microdistrict, including residential buildings, schools, and clinics [13]. As of 2022, Lvivteploenergo had 522 individual heat points, which is almost 30% of the buildings served.

After the full-scale invasion of the Russian Federation into Ukraine, the use of cogeneration plants for the simultaneous generation of electric and thermal energy of individual structures was increased. The procedure for the construction or placement of cogeneration plants for the period of martial law was simplified in accordance with the resolution of the Cabinet of Ministers of Ukraine dated May 14, 2024 No. 547. Thus, the construction and placement of gas piston and gas turbine plants with a capacity of 1 MW and more is carried out without the need to obtain a number of permits that are required in peacetime. This allows significantly reducing the time for preparation for construction and responding faster to energy challenges.

Many solutions for using alternative energy sources as energy resources in district heating systems are at the stage of scientific developments. For example, [14] describes the possibility of using wood waste from a woodworking enterprise to produce generator gas, which can then be used to produce thermal energy in a boiler house. The authors of [15] propose using the heat of wastewater to obtain thermal energy. There is also the possibility of using geothermal waters in heating systems. Depending on their composition, they can either be directly fed into the heating system or used to heat the heat carrier of the heating system in an intermediate heat exchanger [16].

In the European Union countries, 4th generation district heating systems (4GDH) are currently being actively promoted and gradually implemented, the main requirements for which are the use of alternative energy sources for heat generation, the use of low-temperature coolant, equipment for heat accumulation, pre-insulated pipelines, heat metering devices, and devices for regulating the release of thermal energy [17].

Therefore, in the post-war reconstruction to increase the energy efficiency of the heat and power sector, the main concept should be geared towards designing new infrastructure using new technologies in compliance with the indicators of the 4th generation heat supply system and the requirements for "efficient district heating". It is clear that most of the proposed measures require significant capital investments and can be postponed in time, so it is important to find out the opinion of Ukrainian citizens, which measures during the reconstruction of district heating systems are a priority for them.

In Ukraine, studies have been conducted that touched the reconstruction, including the energy sector. Thus, in 2023, a sociological research was conducted by the Info sapiens research agency by the Transparency International Ukraine to identify the fears of Ukrainians in reconstruction, as well as to identify approaches and their priorities [18], [19]. The survey received 1012 citizens and business representatives. According to 77% of citizens and 81% of business representatives, corruption is one of the main problems in Ukraine. The main principles of reconstruction, according to the vast majority of respondents, should be: decentralization of funds, early strategy of reconstruction of Ukraine, transparency and openness of rebuilding, attracting citizens and business, quality of work as a priority. Regarding the sector of the reconstruction, 45 % of respondents called the restoration of critical infrastructure. After

that, the housing is significant for Ukrainians, for those who lost it, the demining of territories, the restoration of work of hospitals, schools, kindergartens, adaptation of the military to a peaceful life.

In February 2025, Rating Sociological Group conducted a national survey "Energy Situation in Ukraine expectations, challenges and prospects", the results of which were information about how Ukrainians see: they see the situation with energy in general, evaluate the power of power in the energy sphere [20]. The sample included 1200 respondents. Regarding the authorities', measures to improve the energy situation in Ukraine, respondents noted the restoration of destroyed energy (48%), strengthening of protection of energy (38%), raising funds and energy equipment from international partners (37%). 69% of respondents consider the actions of the authorities to improve the situation in energy effective, ineffective actions of the authorities consider 25%.

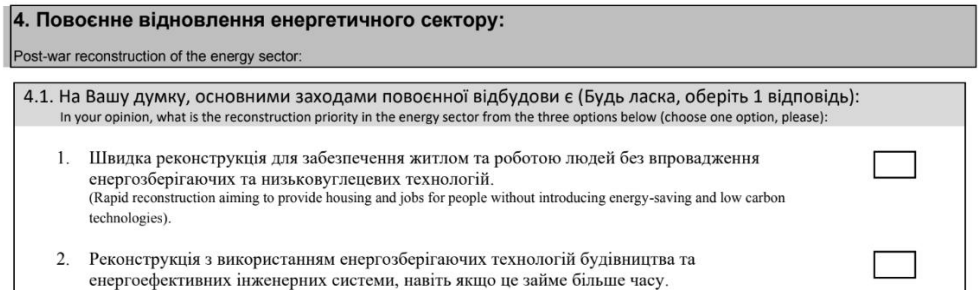
The cited studies have not identified the opinion of the population of Ukraine on measures to restore the thermal power sector, in particular the district heating systems.

3. Aim of work

The aim of this study is to identify the main priorities of Ukrainian citizens in the post-war reconstruction of district heating systems. This was achieved through an online survey conducted as part of the project by conducting an online survey, which took place as part of the project "Russian-Ukrainian War – Assessment of the Level of Destruction in the Affected Cities of Ukraine".

4. Methodology

In order to evaluate the extent of destruction, as well as the determination of priorities in citizens of Ukraine in the post-war reconstruction, a research project "Russian-Ukrainian War – Assessment of the Level of Destruction in the Affected Cities of Ukraine" was conducted. The results of the research should ensure that the post-war reconstruction efforts align with the priority needs of a particular community. To achieve this goal, a methodology was used on the basis of a survey, which gives priority to broad cover, representativeness and feasibility in difficult conditions. The survey questionnaires were distributed and collected electronically, adhering to recommended practices for remote survey administration. This research approach has proven effective in previous studies, addressing the practical challenges posed by Ukraine's unstable conditions and enabling engagement with respondents across diverse regions [21], [22]. The survey form was produced with help of JISC, a non-profit organization from the United Kingdom that provides IT services and digital resources to support research (Fig. 1). The results of this survey will be able to help develop a strategic reconstruction plan of Ukraine in the future.


4. Повоєнне відновлення енергетичного сектору:

Post-war reconstruction of the energy sector:

4.1. На Вашу думку, основними заходами повоєнної відбудови є (Будь ласка, оберіть 1 відповідь):
In your opinion, what is the reconstruction priority in the energy sector from the three options below (choose one option, please):

1. Швидка реконструкція для забезпечення житлом та роботою людей без впровадження енергозберігаючих та низьковуглецевих технологій.
(Rapid reconstruction aiming to provide housing and jobs for people without introducing energy-saving and low carbon technologies).

2. Реконструкція з використанням енергозберігаючих технологій будівництва та енергоефективних інженерних системи, навіть якщо це займе більше часу.

Fig. 1. Fragment of an online survey form.

Participation in the survey was voluntary for respondents. Even after starting to answer the questions, the respondent could refuse to fill out the survey form and not send their answers at any time. The survey also took into account the principles of confidentiality, so it did not involve the collection of any information that could be used to identify the participants. Before starting the data collection work, the created survey received ethical approval from a leading research institution.

The survey consisted of an introduction and three groups of questions. The introduction described the purpose and objectives of the study, the ethical interpretation of the participants' responses, and the requirements for the confidentiality of the results obtained. The first group of questions concerned some personal data of the survey participants, in particular, it was necessary to provide information about the place of residence before the start of the full-scale Russian invasion of Ukraine and during the survey, the age and field of activity of the survey participant, as well as the level of destruction of the settlement during the hostilities. The second group of questions concerned the primary needs and priorities of the post-war period for the inhabitants of Ukraine. Respondents were asked to identify their first, second, and third priorities for post-war reconstruction from seven options, including demining or rebuilding energy infrastructure, housing, healthcare facilities, education, transport infrastructure, or preserving and restoring cultural heritage sites. The third group of questions concerned post-war reconstruction of the energy sector. All questions used a multiple-choice format, which allowed for the collection of structured quantitative data. In addition, an open-ended question was offered, which allowed respondents to express their own opinion, different from the proposed answers. The online questionnaire was designed so that the respondent would spend no more than 10 minutes on its processing. Ethical approval was obtained from a leading research institution before the start of data collection. Recognizing the importance of cultural and linguistic relevance, the survey was conducted in Ukrainian.

To ensure the reliability of the results obtained, the required sample size was established based on the number of adult Ukrainians, which, according to IMF data, was estimated at approximately 26.2 million people in 2023. The standard sample size formula for proportions [23] was used to calculate the required sample size:

$$n = (z^2 \cdot p \cdot (1 - p))/d^2, \quad (1)$$

where n is the required sample size; z is the value of the normal deviation corresponding to the desired level of confidence; p is the expected proportion of the population that exhibits the characteristic of interest; d is the margin of error.

At a confidence level of 95%, an expected population proportion of $p = 50\%$ and a standard error of $d = 5\%$, the required sample size is 384 residents. Existing studies show that the average response rate in online surveys is 44.1% [23]. In addition, the results obtained may contain certain shortcomings, for example, the absence of some responses. Therefore, it was decided to distribute 2000 questionnaires, which guaranteed that even after taking into account the outflow of poor-quality questionnaires, the required sample size was met, which increased to 420 respondents.

An important task of the survey was to collect questionnaires from as many settlements in Ukraine as possible and, if possible, to cover all regions. People in Ukraine are distrustful of various surveys and therefore very often ignore them. In addition, part of the territory of Ukraine is under temporary occupation, which prevents direct communication with residents. The survey was conducted during May – July 2024, after another massive shelling of rear settlements, which also contributed to the indifference of the population to the proposed survey.

The invitation to participate in the survey was carried out using a link to an online survey form, which was distributed through social media platforms, professional and personal circles of acquaintances of the project co-authors. On social networks, you could get answers from refugees, people from temporarily occupied territories, and territories where active hostilities were taking place. The professional circle of communication of the co-authors included employees of construction educational institutions, companies for the design, sale and installation of equipment for heat and gas supply and ventilation systems, and students of construction specialties.

This paper will present the respondents' answers that relate only to the reconstruction of the energy sector. Information on the damage caused by the war and citizens' priorities in post-war reconstruction will be provided in the authors' subsequent publications.

5. Research results

420 people from different regions of Ukraine took part in the survey. Age distribution of participants: 45% were aged 18 to 30, 24% – from 31 to 40, 20% – from 41 to 50, and 11% were over 51. As for the field of activity, 60% of participants reported that they were working, 5% – pensioners, 27% – students, and 8% – unemployed. Of the surveyed respondents, 65% stated that they did not leave their places of residence due to the war, 10% stated that they

were internally displaced persons in their regions, 1% of participants indicated that they were refugees abroad, 24% did not answer the question about their current place of residence. The geographical location of respondents before the full-scale Russian invasion of Ukraine: 29% of participants were from Lviv, 11% from Kyiv, 5% from Poltava, 3% from Odesa, 3% from Kharkiv, and 49% from approximately ninety cities and towns throughout Ukraine. As for the first priority in post-war reconstruction, approximately 42.7% of participants indicated the reconstruction of energy infrastructure as the main priority, and another 34.7% put it in second place. That is, 77.4% of respondents noted that energy infrastructure, namely electricity, heat, and water in their homes, was extremely important in their lives.

To determine how it is possible to restore the energy infrastructure two questions were proposed. The first question "In your opinion, the main measures of post-war reconstruction are:" had three answers: 1 – "Rapid reconstruction to provide people with housing and work without the introduction of energy-saving and low-carbon technologies", 2 – "Reconstruction using energy-saving construction technologies and energy-efficient engineering systems, even if it takes more time", 3 – "Rapid reconstruction of the housing sector without energy-saving measures, but using energy-saving construction technologies and energy-efficient engineering systems for infrastructure facilities". Figure 2 illustrates the preferences of Ukrainian residents regarding post-war reconstruction of the energy sector.

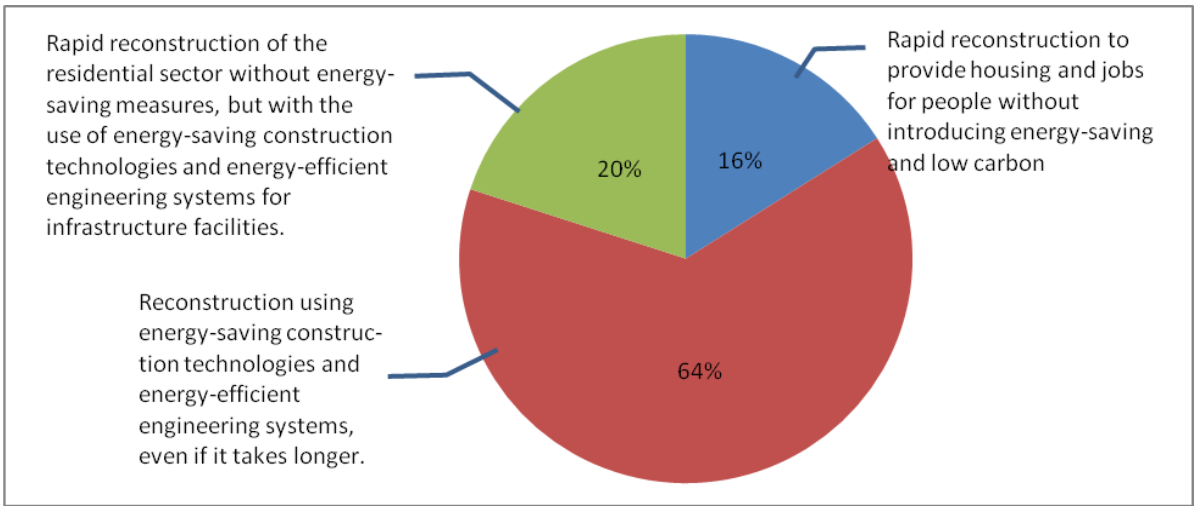


Fig. 2. People's priorities for rebuilding the energy sector

As can be seen from Fig. 2, the majority of respondents (64%) indicated that reconstruction should prioritize the use of energy-saving construction technologies and energy-efficient engineering systems, even if it takes more time. A smaller proportion (20%) supported rapid reconstruction of the residential sector without focusing on energy-saving measures but still incorporating energy-efficient infrastructure. Only 16% preferred rapid reconstruction aimed at providing housing and jobs for people without prioritizing energy-saving or low-carbon solutions. These results suggest that a significant portion of Ukrainian citizens value long-term energy efficiency over speed in reconstruction. One possible explanation for the relatively low selection of the rapid reconstruction option is that many respondents may not have been immediately affected by housing loss or destruction during the hostilities, allowing them to prioritize sustainability rather than urgent shelter needs.

The second question in the third group was worded "Are you willing to pay more for district heating services if…" Respondents were offered five answers: 1 – "Imported natural gas will not be used as fuel", 2 – "Greenhouse gas emissions will be reduced", 3 – "Renewable and/or alternative energy sources will be used (wood waste, agricultural waste, household waste, biogas, etc.)", 4 – "Not willing to pay more for district heating services", 5 – "I have an individual heating system" (Fig. 3).

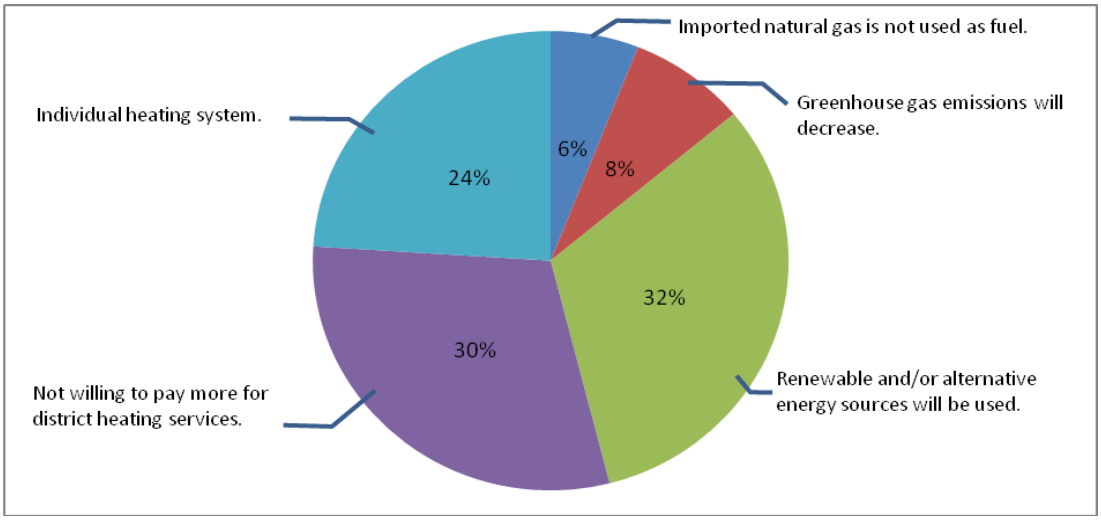


Fig. 3. Respondents' attitude towards increasing the cost of district heating services.

According to the survey data presented in Fig. 3, more than 30% of respondents are not willing to pay more for district heating services, reflecting a notable level of price sensitivity. Among the 76% of participants who currently use district heating, this equates to almost 40% who are unwilling to support a tariff increase. However, there is also a considerable portion of the population open to change. 46% of respondents expressed willingness to accept higher heating tariffs provided certain conditions are met. The most widely supported reason for a potential price increase is the transition to renewable and/or alternative energy sources, with 32% of respondents prioritizing this option. Other motivations include reducing greenhouse gas emissions (8%) and minimizing reliance on imported natural gas (6%). Interestingly, 24% of respondents favor individual heating systems over district heating, signaling a desire for greater autonomy or efficiency in energy use.

The results of the study provide new insights into people's priorities in the reconstruction of the energy sector, in particular district heating systems, which can help in developing an adaptive reconstruction plan for the country. The results obtained are largely consistent with people's priorities presented in the literature. The survey showed that 64% of Ukrainians are ready to wait for the post-war reconstruction of district heating systems, provided that energy-saving construction methods and energy-efficient engineering solutions are implemented. In addition, the data obtained indicate that, although there is resistance to the increase in heating costs, a significant part of the population (32%) is ready to invest in sustainable energy solutions. These results highlight the critical role that renewable energy sources play in the reconstruction of the energy infrastructure, in particular district heating systems, and the energy independence of Ukraine. However, the results of the study demonstrate some differences in the views of the population regarding the priorities for the reconstruction of the energy sector, which also need to be taken into account to meet the needs of local communities in the country.

6. Conclusion

The article presents and analyzes the results of an online survey conducted as part of the project "Russian-Ukrainian War – Assessment of the Level of Destruction in the Affected Cities of Ukraine" which aimed to identify to determine the main priorities of Ukrainian citizens in the post-war reconstruction of energy facilities and directly of district heating systems. The survey consisted of an introduction and three groups of questions, with the third group addressing the restoration of the energy sector after the war.

For the reliability of the results of the online survey, the required sample size was established, namely 420 questionnaires, the value of which was determined based on the number of adult Ukrainians. According to the survey results, 42.7% of respondents indicated that the first priority in post-war reconstruction for them is the restoration of energy infrastructure. This indicates the extreme importance for citizens of energy infrastructure, which allows them to maintain heat and electricity in their homes and have stable job.

When asked what measure of post-war reconstruction of the energy sector they consider the main one, 64% of respondents chose the answer "Reconstruction using energy-saving construction technologies and energy-efficient engineering systems, even if it takes more time" 32% of respondents are willing to pay more for district heating services if alternative energy sources are used for the production of thermal energy. Analysis of the responses received indicates the energy awareness of a significant number of Ukrainian citizens who understand the importance of the energy sector for the national economy. Notably, their readiness to support the transition to alternative energy sources – even at personal financial cost – signals a collective commitment to achieving greater energy independence and sustainability in the post-war period.

7. Acknowledgment

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Пріоритети населення щодо повоєнної відбудови енергетичного сектору України

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Анотація

Російське вторгнення в Україну призвело до масштабних руйнувань багатьох міст по всій країні. Хоча війна ще не закінчилася, настане час, коли конфлікт завершиться, і розпочнуться зусилля з відбудови. Світовий досвід показує, що першим кроком у підготовці до післявоєнної відбудови є оцінка рівня руйнувань. Крім того, важливо розуміти потреби та пріоритети людей. В іншому випадку, заходи з відбудови можуть не вирішити існуючі проблеми та реальні потреби місцевих громад. Це дослідження має на меті дослідити пріоритети післявоєнної відбудови українців, зосереджуючись на енергетичному секторі та, зокрема, на об'єктах централізованого теплопостачання. Під час бойових дій значна частина енергетичної інфраструктури України була пошкоджена або зруйнована, що буде важливим сектором у відновленні інших секторів. Дослідницька робота включала проведення онлайн-опитування з питаннями, що зосереджувалися на оцінці українцями важливості відбудови енергетичного сектору. В опитуванні взяли участь 420 осіб з різних регіонів України, різних вікових груп та професійного досвіду. Результати показують, що енергетична свідомість значної кількості громадян України висока. Таким чином, на запитання, який захід післявоєнної реконструкції енергетичного сектору вони вважають одним із найважливіших, 64% респондентів обрали відповідь «Реконструкція з використанням енергозберігаючих будівельних технологій та енергоефективних інженерних систем, навіть якщо це потребує більше часу». Крім того, 32% респондентів готові платити більше за послуги централізованого теплопостачання, якщо для виробництва тепла використовуватимуться альтернативні джерела енергії.

Ключові слова: онлайн-опитування; енергетична інфраструктура; системи централізованого теплопостачання; повоєнна відбудова; пріоритети; альтернативні джерела енергії.